Utility and Grid Operator Resources for Future Power Systems Webinar Series

Customer Rate and Tariff Design

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Webinar Series

July 17, 2025

Agenda

1. Background: Cost of service rate regulation
2. Cost of Service: Drivers of utility costs
3. Pressures: Evolving grid prompting rate design changes
4. Customer Response to Rates: Retail price signals to load and their limits
5. New methods for evaluating rates
6. Q&A

Cost of Service Rate Regulation

Balancing competing and evolving criteria

What's in a (Residential) Bill?

- Previous balances or credits
- Delivery and supply charges
  - Fixed charges ($/month)
  - Volumetric charges ($/kWh)
    - Vary by month or day or both
    - Can increase or decrease with consumption (blocks)
- Less often residential customers may see demand changes ($/kW)
  - Coincident or non-coincident
- Minimum bills, nonbypassable charges for solar PV adopters
- Riders, taxes, surcharges

Regulatory Oversight

- Regulatory criteria for evaluation of utility costs, rate of return, rate design, etc., used by Public Utility Commissions
  - **Objective**: Bonbright principles, cost causation, just and reasonable, used and useful, etc.
    - Can be hard to quantify, especially with any granularity!
  - **Subjective**: politics, economic development priorities (e.g., attracting industry with lower rates), etc.
    - Hard to elucidate, let alone measure
- Utilities may face barriers in exploring novel rate designs if regulators do not know how to evaluate the tradeoffs within these proposals.

Traditional and Novel Ratemaking Objectives

Bonbright - Classic

- Rate Attributes:
  - Simplicity
  - Understandability
  - Public acceptability
  - Feasibility of application
- Yields revenue sufficiency
- Supports revenue stability year to year
- Support rate stability year to year
- Supports fairness in apportioning costs of service
- Avoids undue discrimination
- Promotes efficiency

Source: Bonbright (1961)

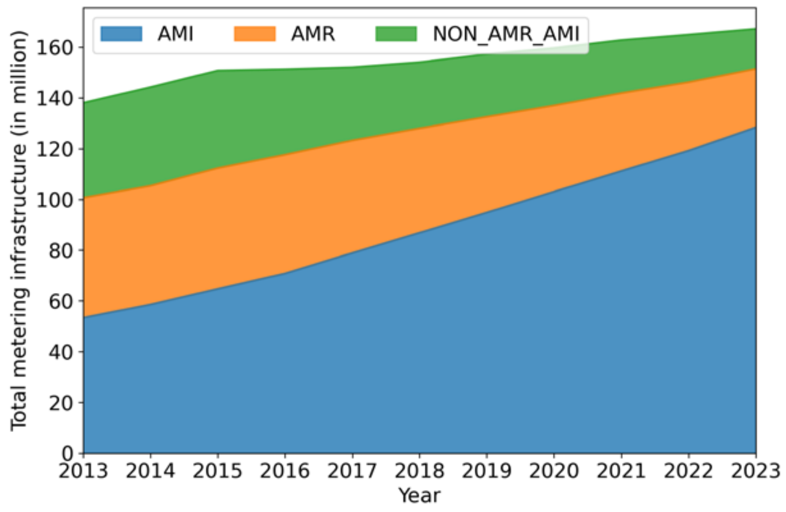
Newer objectives

- Promote energy affordability for low-income customers
- Promote new technology adoption
  - Electrification
  - Energy efficiency
  - Solar photovoltaic (PV)/Storage
- Incentivize demand flexibility
- Reduce power system emissions

Looking at Today

Background

- Historically, rates have been simple
  - Limited ability to meter customer consumption in detail
  - Relatively stable upstream prices
- Now, there is widespread advanced metering infrastructure, ***and*** some costs are becoming more variable (e.g., intraday variations in energy cost) while some fixed costs are steadily increasing.
- Economic theory states that marginal cost pricing is most efficient. Bonbright indicates cost-causation is a core regulatory principle.
  - Households (and regulators) tend to dislike price variability.



NREL Analysis: U.S. Energy Information Administration (EIA) 861

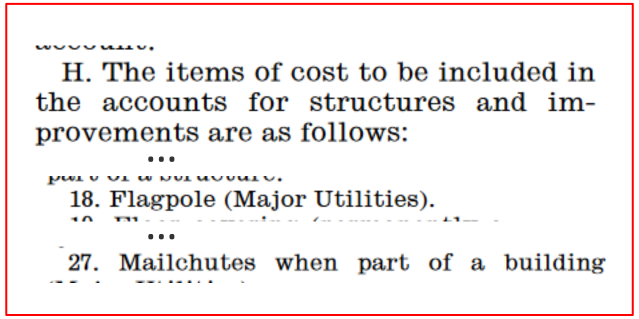
- In the residential space, there is still relatively minor uptake of time-varying rates.

Source: 2023 EIA-861	
Advanced metering infrastructure share across all utilities	**~90%**
Share of residential customers on dynamic (time-varying) rates	**~9%**

This is not at all uniform by state or utility—lots of outliers with higher participation!

Translating Detailed Accounting Into Rough Prices

Image credit: Structures and Improvements (2021)


H. The items of cost to be included in the accounts for structures and improvements are as follows:

...

18. Flagpole (Major Utilities).

...

27. Mailchutes when part of a building

Flat volumetric energy charge ($/kWh)

Monthly customer charge ($/month)

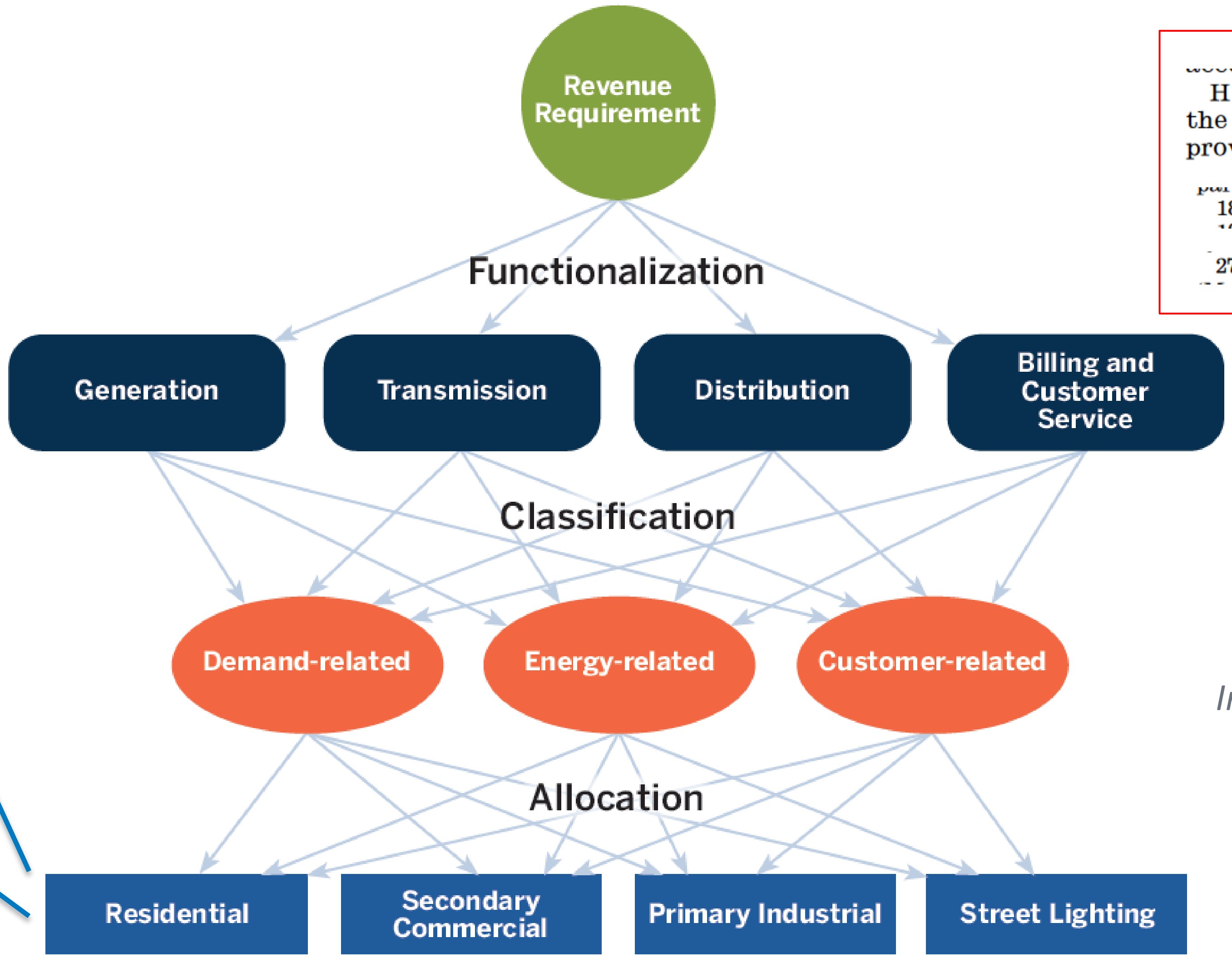
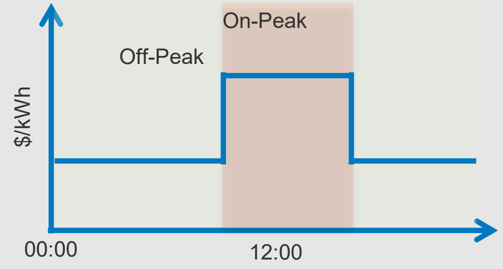


Image credit: Lazar, et al., (2020); Kavulla (2023). Original figure licensed under [CC BY-NC 4.0](CC BY-NC 4.0).

Evolution of Price-Plans

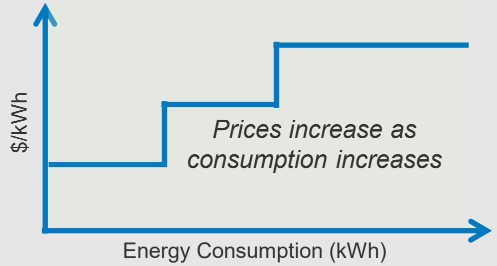
Flat Rate

To encourage flexible demand and energy efficiency, some utilities introduced TOU or stepped tariff structures.



Time-of-Use (TOU)

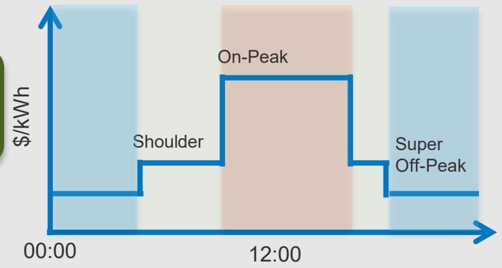
Flexible Demand, On-Peak Energy Reduction



Incremental Block Tariffs

Energy Efficiency

Multi-Tier



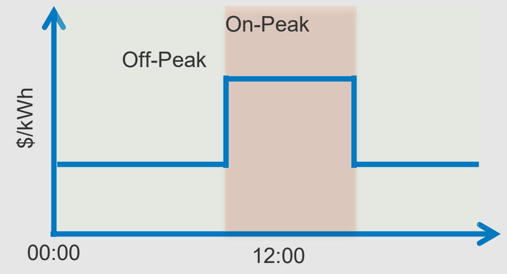
Electric Vehicles

To accommodate electric vehicles, some utilities introduce a super off-peak to encourage night charging.

To encourage solar PV adoption, utilities introduce net energy metering.

Net Energy Metering

DER Generation

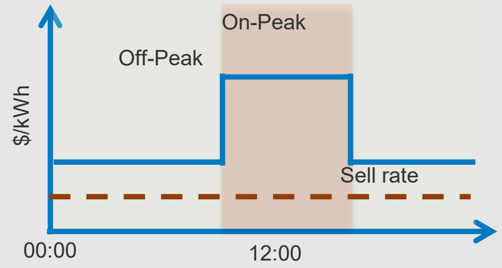


$/kWh received = $ kWh delivered

As solar adoption increases, to recover fixed costs, some utilities introduce net billing, nonbypassable charges, minimum bills

Net billing | Minimum bills | Nonbypassable charges

DER Generation

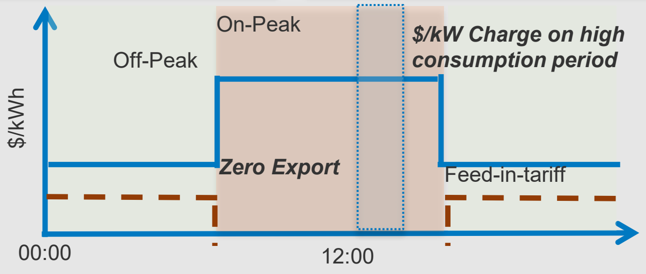


$/kWh received < $/kWh delivered

As solar adoption further increases, some utilities encourage customers to adopt storage to use generation locally.

Distributed Energy Resource (DER) Storage

Zero Export | Demand-Charge



Period of no export | ***$/kW Demand Charge***

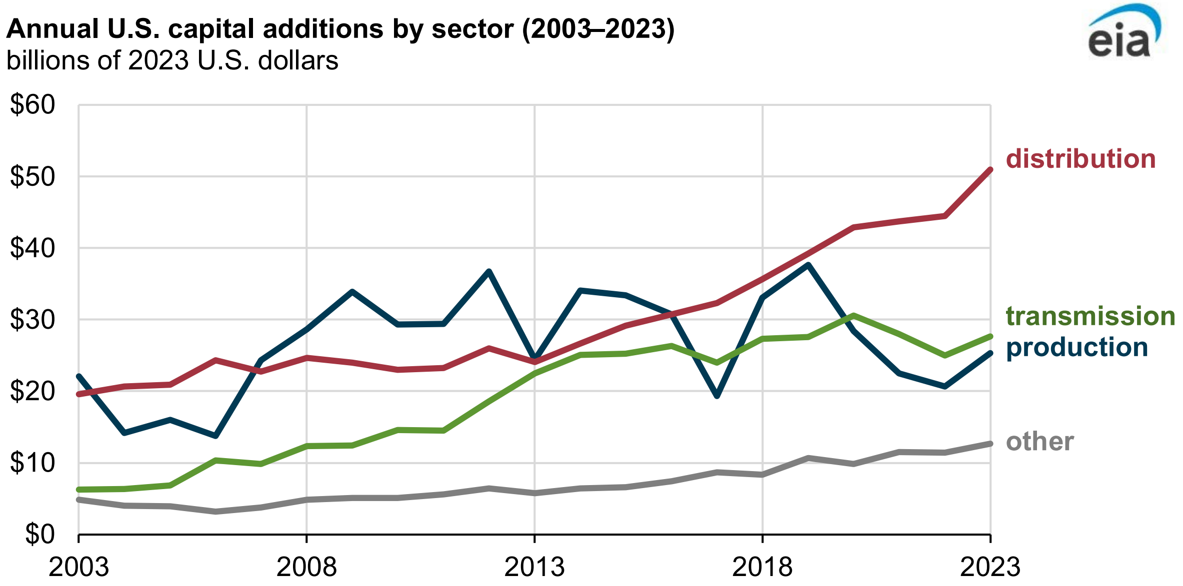
Transactive energy markets | Distributed nodal pricing | Distributed ancillary services

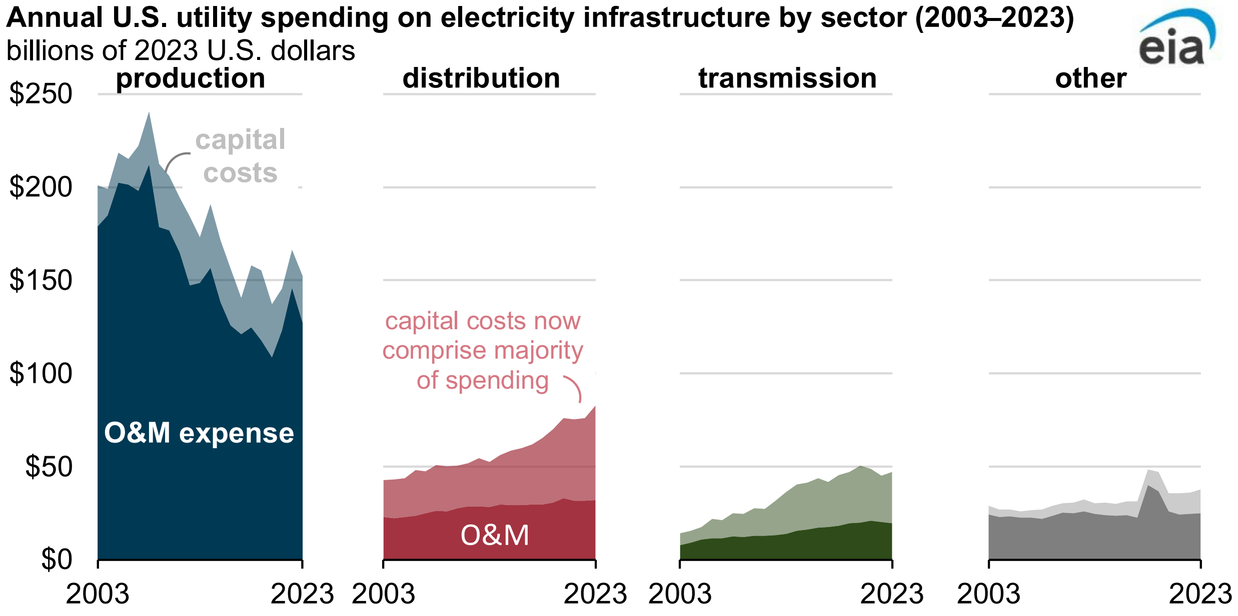
Drivers of Utility Costs

Near-term status

Grid Infrastructure Investments

- Investments in electric infrastructure are driven by new customers, aging infrastructure, resilience investments, and load growth.
- Federal Energy Regulatory Commission reporting showed annual spending increased by 12% from 2003 to 2023 in real 2023 dollars.
- The rate of investment in distribution and transmission infrastructure continues to increase.

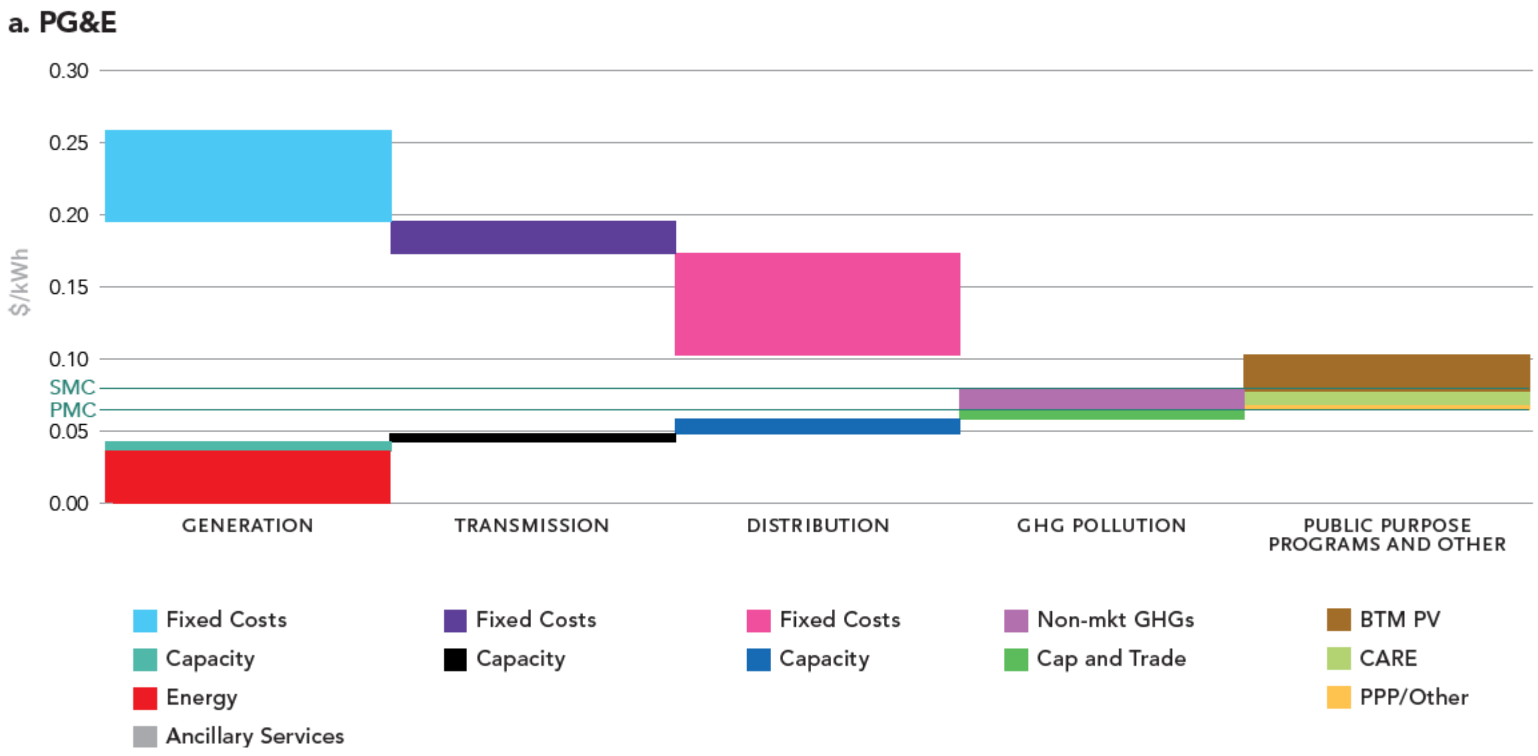




Source: U.S. Energy Information Administration (2024)

Fixed Cost Recovery

- Fixed costs (G/T/D) now make up more than 50% of residential customer bills for California's three main investor-owned utilities.
- Traditional method of recovering these fixed costs through volumetric charges leads to cost-shifting
- How to recover these costs when cost causation cannot be established?
- What is "fair," "non-discriminatory," "affordable," and politically feasible?
  - No single, universal answer



Adapted from: Borenstein et al. (2021)

More (Potential) Drivers to Costs

Changing Loads / Patterns

- New large loads (e.g., data centers, increased manufacturing)
- Growing electric vehicle (EV) adoption and unmanaged charging
- Building electrification driving changes in seasonal peaks
- More variable generation, more energy storage
- More distributed energy resources, smart assets

Macro-trends

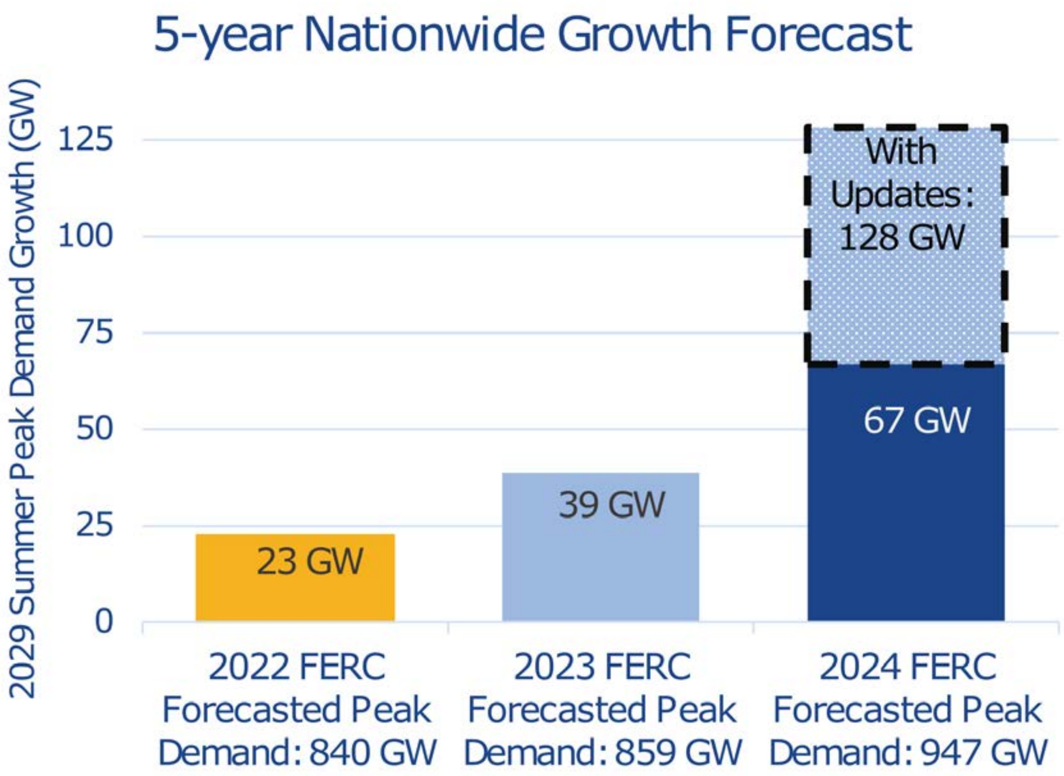
- Rising costs of serving load (e.g., inflation)
- Major weather events
- Aging infrastructure, resilience enhancements

Will these resources increase utilization of existing assets?

Will they require significant new, but infrequently used assets?

Large Loads

- Rapid level of load growth after relatively flat period
  - Data centers, new manufacturing, hydrogen, oh my!
- Significant uncertainty (phantom loads) adds to challenges and risks
  - Who is left holding the bill for investments in new capacity when load does not materialize or data centers leave?
- New large single point loads can exhibit significant price responsiveness (e.g., crypto mining)



Adapted from: Wilson et al. (2024)

A fraction of proposed data centers will get built. Utilities are wising up.

One expert estimated that speculative interconnection requests were five to 10 times more than the number of actual data centers, but the scale of the problem remains elusive.

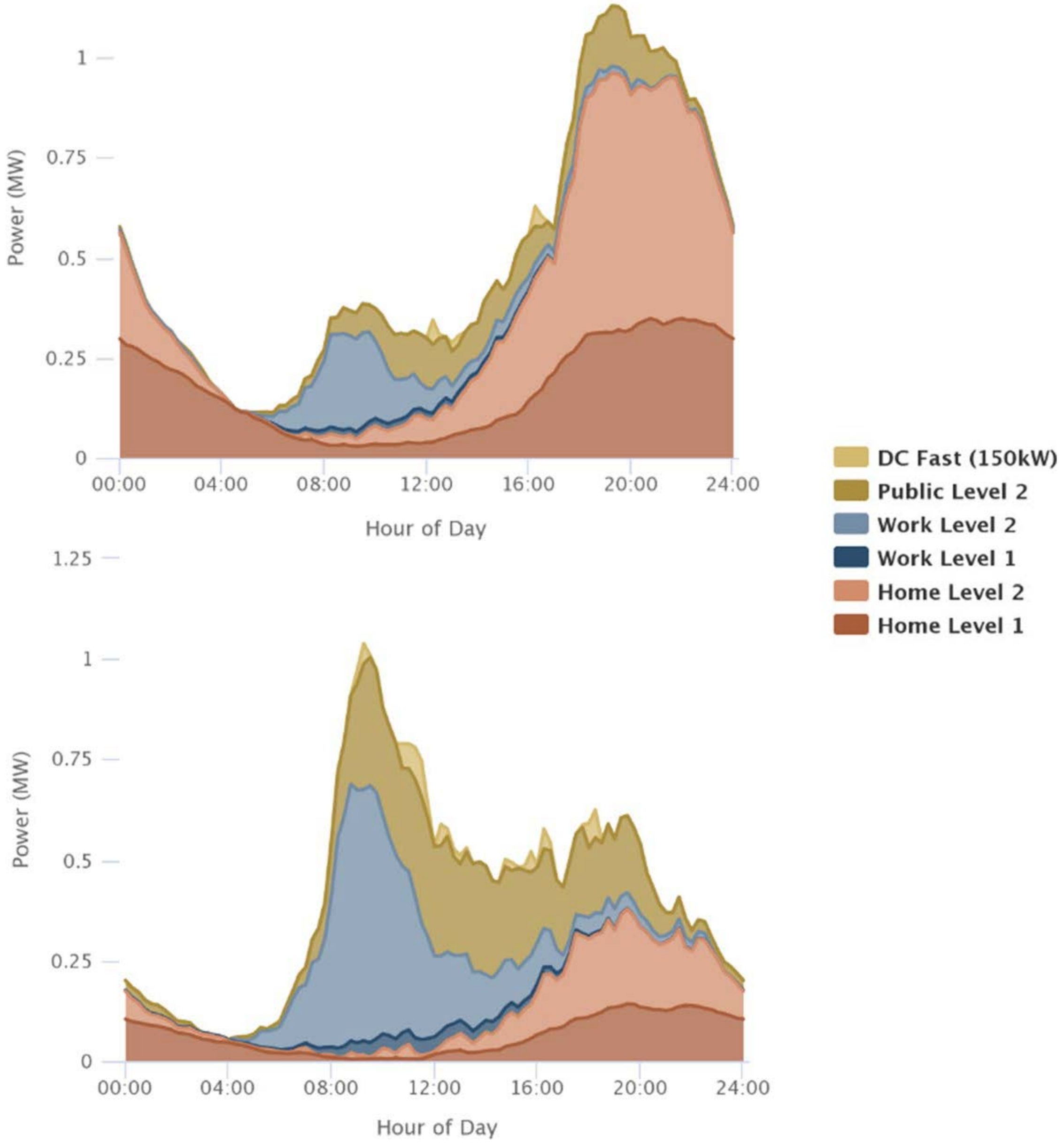
Published May 15, 2025

Image credit: (May 15, 2025) (article link)

Electric Vehicle Adoption

- Growing adoption, not uniformly distributed across country
  - Clustering of adoption from peer effects
- Challenges (and opportunities!) at both bulk power and distribution levels
  - Overloaded lines and transformers
  - Voltage excursions (load spikes)
  - Potential to absorb low-marginal-cost solar PV
- Whether EVs drive significant cost increases will be determined on how they are charged

When EV loads occur depends on ***where*** they occur!

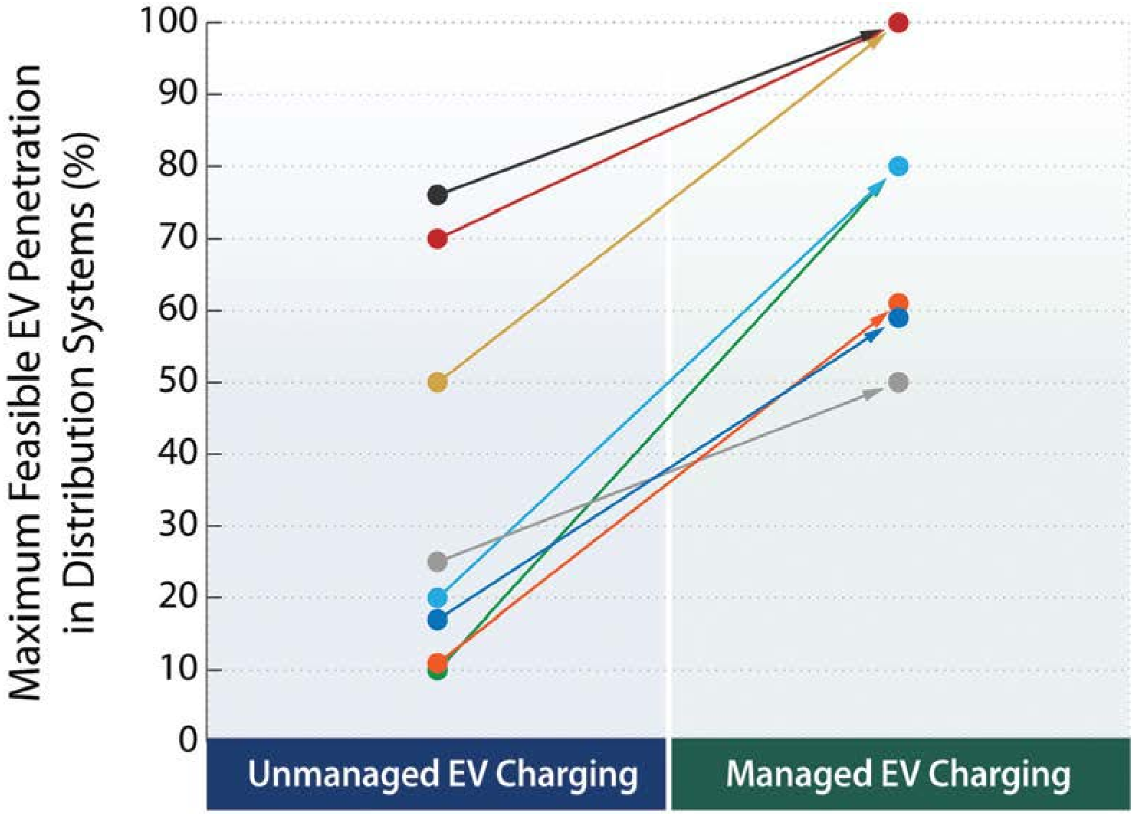


Source: Panossian et al. (2022)

EV adoption (cont.)

"potential of EV managed charging to increase the maximum feasible penetration of EVs in distribution systems ***without implementing additional network upgrades or violating operational constraints****"*

Source: Anwar et al. (2022)



Source: Anwar et al. (2022)

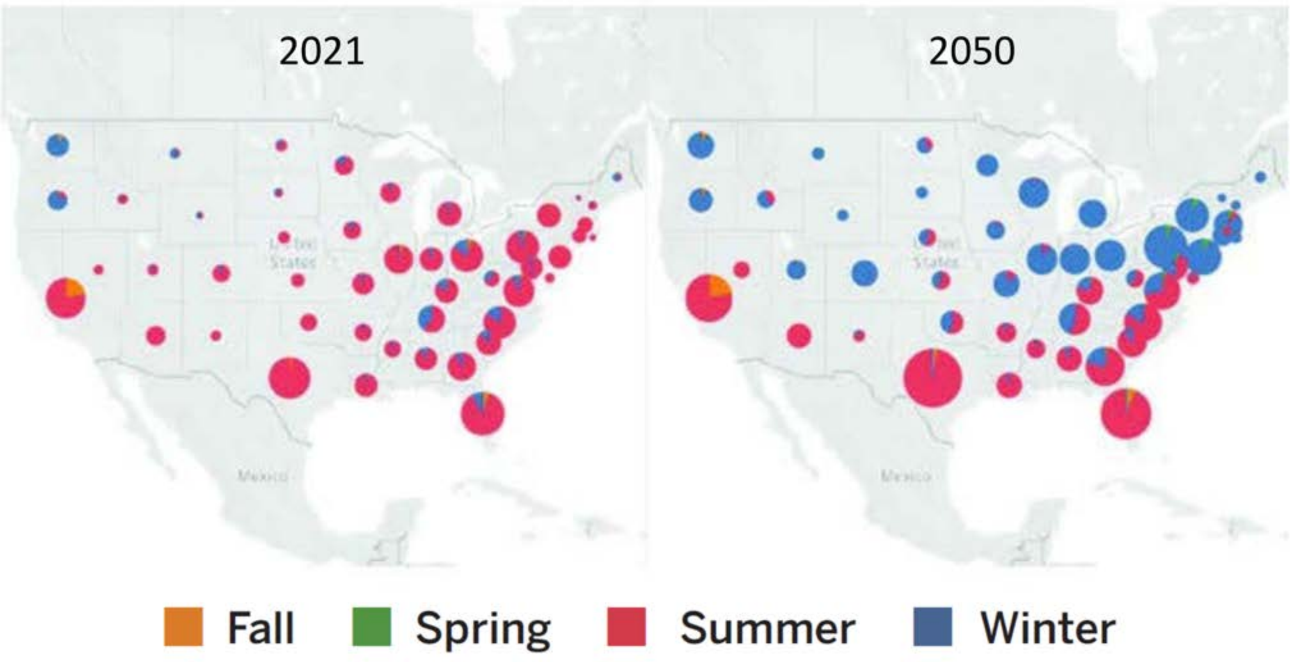
Several studies showing a significant difference in the hosting capacity for EVs based on managed charging

Magnitude of cost impacts from EVs dependent on how they are charged, which can be influenced by (among other things) rate design

Building Electrification (Heating)

- Impacts will be regional:
  - Current heating/cooling loads
  - Dominant heating fuels
- Heat pumps can potentially *lower* summer peaks (more efficient) but increase winter peaks.
  - Less aligned with solar generation
  - Prolonged peaks without diurnal pattern of summer-peaks during winter storms
  - Dual peaking

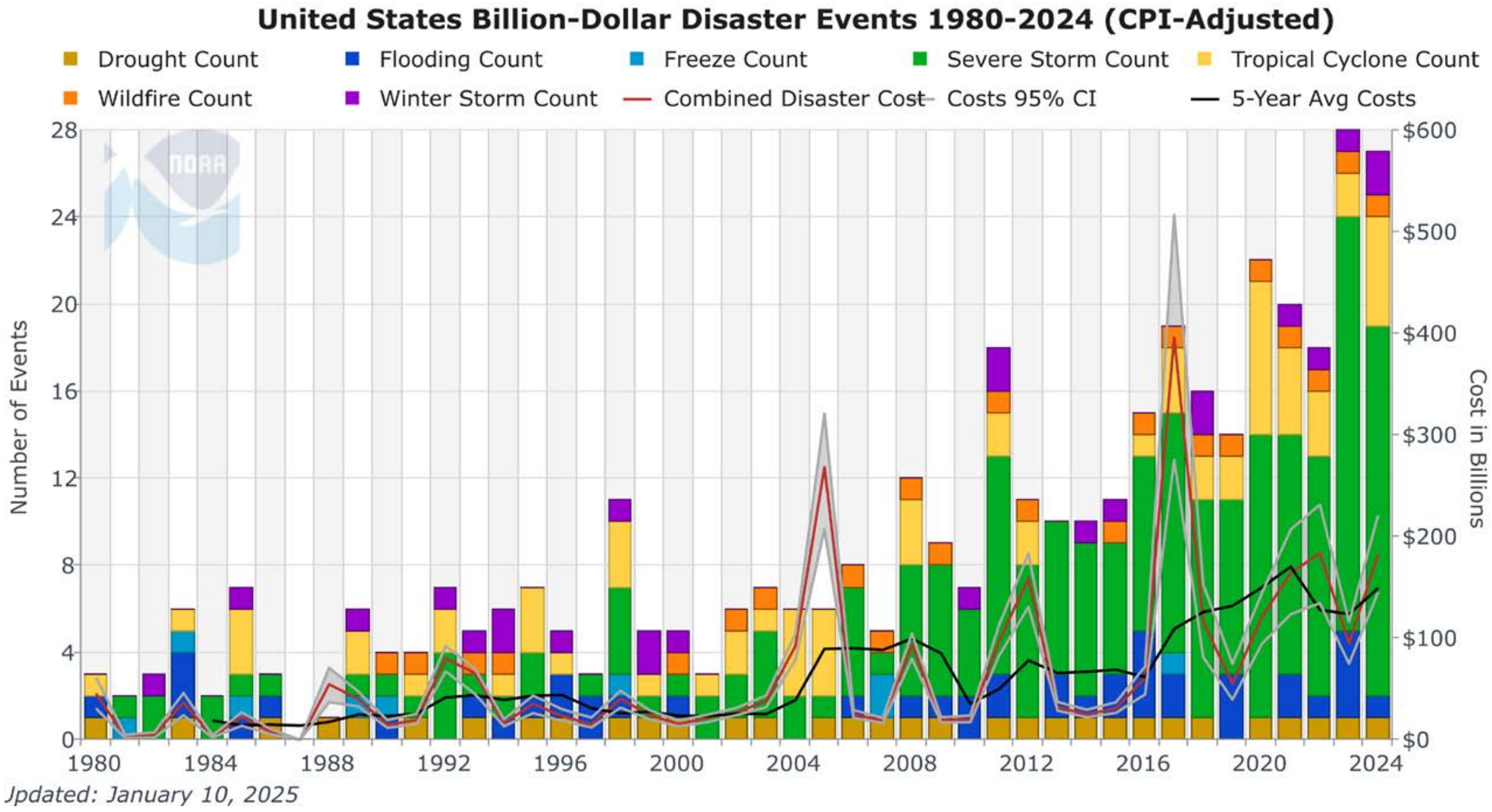
Forecasted Top 100 Load Hours by Season



Adapted from: Energy Systems Integration Group (2024)

Weather-related Costs on the Rise

- Weather-related costs (including costs to utility) increasing over time
- Grid-hardening and replacing infrastructure often funded through rates



NOAA National Centers for Environmental Information (2025)

Potential Takeaways?

- Marginal costs potentially becoming more variable due to seasonal and intraday changes in supply and demand
- "Fixed" costs increasing as component of utility revenue requirement due to growing capital investments
- End-use electrification changing load shapes and creating peakier loads, but increases share of responsive load
- Growing costs from weather events, potential cost increases from large loads

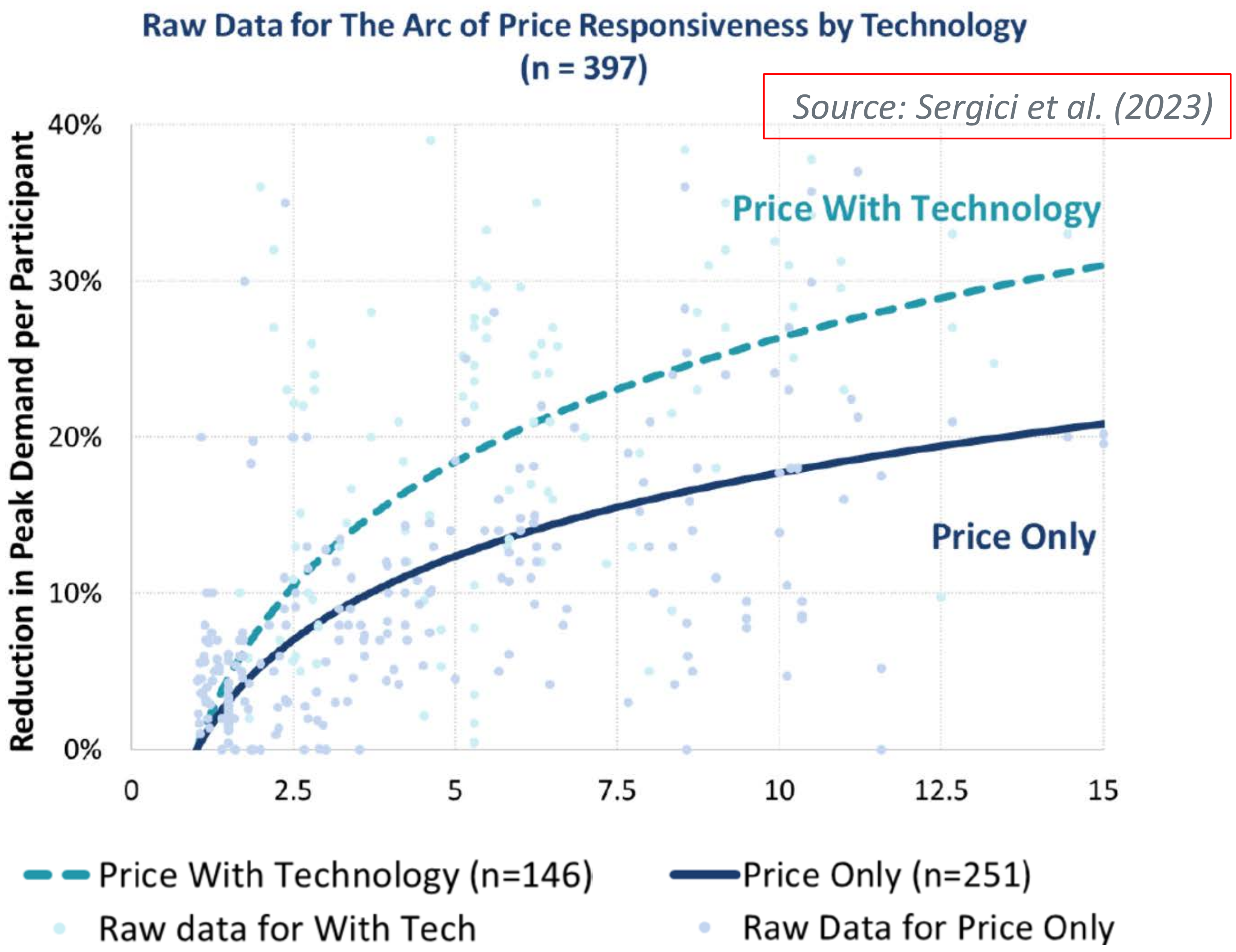
Costs (and opportunity costs) of business as usual with rates potentially growing

Opportunities for enabling demand flexibility

Can customer load shifting save money?
(a ***very*** brief overview)

Do Customers Respond?

- Time-varying rates have been shown to induce customer responses in aggregate
- Reduction influenced by price differential, presence of enabling technologies, information to customers, and season



Savings by Category

Cost Category	Degree to Which the Response Must:			Degree of Load Diversity	Avoidability Rating
	Occur in Specific Hours	Occur in Specific Locations	Be Predictable and Reliable		
Fuel and GHG Emissions	Mid	Low	Low	High	★★★★
Generation Capacity	High	Low	High	High	★★★
Transmission Capacity	High	Mid	High	High	★★
Distribution Capacity	High	High	High	Low	★

Cost categories that are easy to avoid | Cost categories that are somewhat easy to avoid | Cost categories that are difficult to avoid

Source: Olson et al. (2023)

- Cost savings become increasingly driven by capacity deferral
  - Generation capacity easier than distribution capacity (constrained location ➔ fewer customers, less load diversity)

Pressures and Reactions

Evolving grid is prompting rate design changes

What Changes Are We Seeing to Rates?

Energy	Demand	Fixed	Incentives	Technology
• More time-of-use rates (mandatory: California, opt-out: Long Island Power Authority) • Critical Peak Pricing (CPP)	• TOU demand charges • Coincident vs. non-coincident • Three-part rates	• Increasing fixed charges • Income-based fixed charges • Minimum bills	• Alternatives to net metering (e.g., net billing) • Performance-based utility incentives • On-bill financing for efficiency / electrification investments	• Virtual power plant programs • Electric vehicle specific rates • Heat pump-specific rates • Data center rates

Source: Satchwell et al. (2020)

Electric Vehicle (EV) Rates

- San Diego Gas and Electric
  - Several ***residential*** EV TOU rate (three TOU periods, some with CPP)
  - 3rd party charging with hourly pricing (based on California Independent System Operator day-ahead conditions)

Source: San Diego Gas & Electric (n.d.)

- Some utilities pair (free) chargers or (customer-financed) metering as part of EV package to customers
  - Free chargers: Green Mountain Power
  - Secondary meters: PG&E
- For EV supply equipment, National Grid offers TOU rates with demand charges with discounts based on load factor

Source: Green Mountain Power (2022)

Source: Pacific Gas and Electric Company (2025)

Source: National Grid (2023)

Data Center Tariffs

- AEP Ohio proposed tariff
  - Long-term capacity commitments
  - Minimum billing demand at 90% of contract capacity or highest monthly billing demand
  - 10-year contracts with early exit fees
  - Right to determine security/collateral provisions
  - Mandatory participation in demand response programs

AEP Ohio (2024)

- NV Energy:
  - Tariff that mirrors existing tariffs, but includes an "Energy Supply Agreement" that incorporates data center clean energy needs in regular planning practices
    - For customers with corporate sustainability targets

Public Utilities Commission of Nevada (2024)

Different Rate Components Support Different Objectives

	Revenue Sufficiency	Cost Reflectivity	Bill Stability	Undue Discrimination	Affordability	Simplicity
Fixed	High	Medium	High	High	High	High
Demand	Medium	Medium	Medium	Medium	Low	Low
Energy	Low	Medium	Low	Medium	Medium	Medium

	Electrification	Efficiency	Demand Flexibility	Reliability
Fixed	High	Low	Low	Low
Demand	Medium	Medium	Medium	Medium
Energy	High	High	High	High

Adapted from: Hledik et al. (2025)

Rate Capabilities at NREL

Customer Responses to Price Signals

ResStock™: granular view of housing stock + physics-based load modeling

OCHRE™: simulates controls of residential technologies to see impact on load

Set up, inputs

- Customer loads
- Load flexibility assumptions
- DER adoption
- Tariff designs
- Utility cost structure
- Low-income programs, riders

Optimization / model run

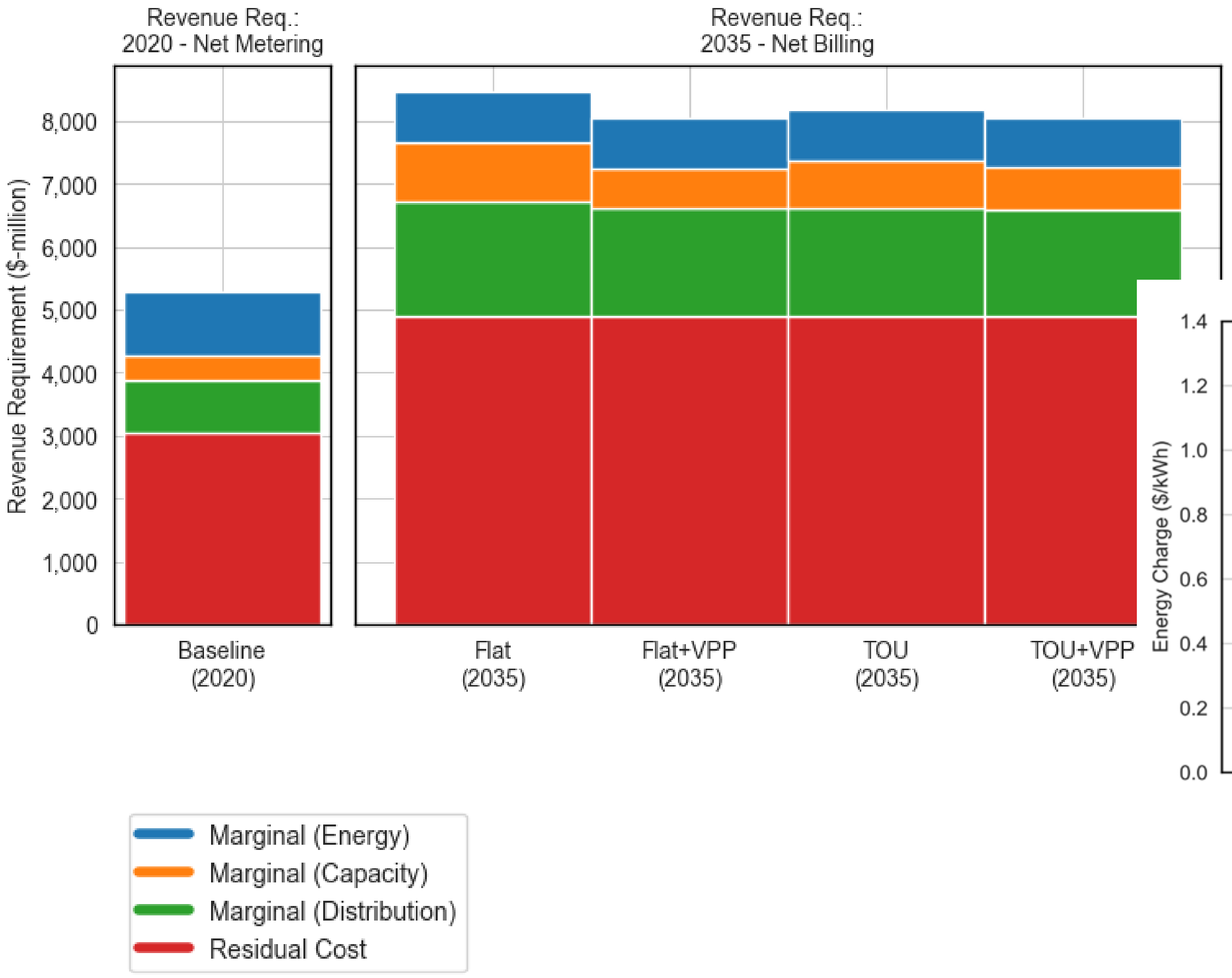
- Calculate revenue requirement
- Estimate rates that achieve revenue sufficiency
- Model bill savings under different load shifting patterns
- Estimate power system savings from new load patterns

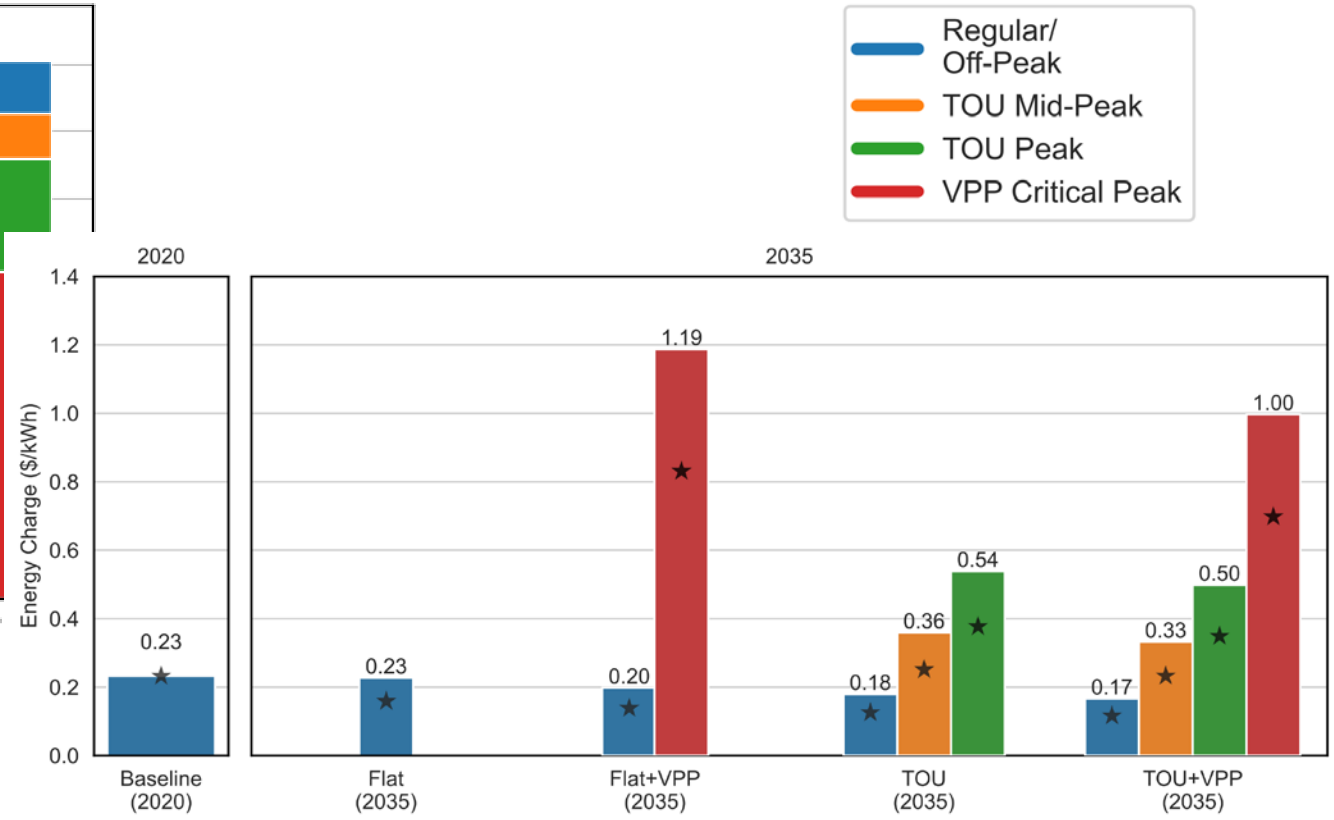
Customer Affordability, Incentives, and Rates Optimization (CAIRO): leverages loads, retail rate inputs, and power system model outputs to estimate utility revenue requirements, rates, bill impacts and customer responses

Processing results

Rates	Evaluation Metrics	Power System
• Customer loads • Customer Bills	• Energy burden • Deadweight loss • Cross-subsidies	• Avoided loads • Avoided costs

Estimating Revenue Requirement, Rates With CAIRO





Source: Bowen et al. (Forthcoming)

Sample Results (cont.)

Rate Equity Metric	2019 LADWP Baseline w. EZ-SAVE	2035 LADWP BAU w. EZ-SAVE	2035 Simplified Tiers	2035 TOU Rates	2035 LADWP BAU w. CARE & FERA	2035 Simplified Tiers w. CARE & FERA	2035 TOU Rates w. CARE & FERA	2035 Simplified Tiers w. IBFC	2035 TOU Rates w. IBFC
Avg. Monthly Bill (All Households)	$105	$188	$188	$188	$188	$188	$188	$188.00	$188
Avg. Monthly Bill (Low-Income, 0-50% AMI)	$83	$193	$178	$179	$151	$138	$138	$81	$81
Avg. Monthly Bill (Solar PV Adopters, all incomes)	$38	$58	$144	$136	$86	$165	$157	$215	$217
Avg. Monthly Bill (Non-adopters, All Incomes)	$107	$220	$199	$201	$213	$194	$196	$181	$181
Transfer Cost ($)*	$10.3M**	$10.4M**	–	–	$335M	$307M	$309M	–	–
Transfer Cost (% – Share of Revenue Requirement)*	0.7%**	0.3%**	–	–	10%	9.5%	9.6%	–	–
Average Annual Electricity Burden for:									
All Households	3.7%	7.2%	6.9%	7.0%	6.4%	6.0%	6.1%	3.8%	3.8%
Low-Income, 0-50% AMI	7.8%	16%	15%	15%	13%	12%	12%	5.9%	5.8%
Moderate-Income, 50-80% AMI	2.1%	4.0%	3.7%	3.8%	4.3%	4.1%	4.1%	3.4%	3.4%
Number of Households Over 100% Electricity Burden	4,800	23,000	20,000	20,000	13,000	11,000	11,000	4,400	4,400

Legend: Baseline; More Affordable ↕ Less Affordable; No Change

* for EZ-SAVE & Lifeline or CARE & FERA

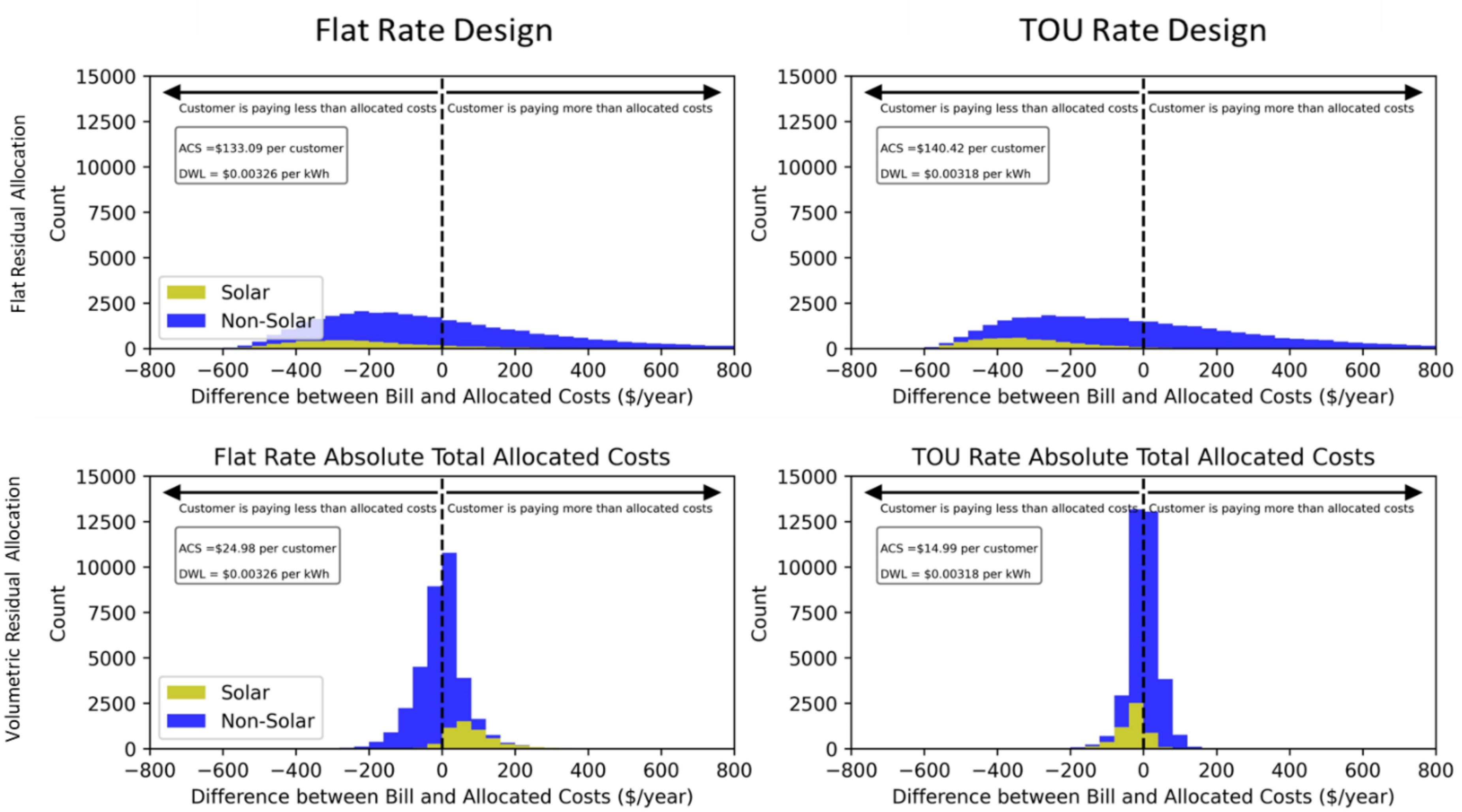
**The model did not recover Lifeline program expenses from the residential revenue requirement, which makes transfer costs lower than if these program expenses were recovered solely from the residential class.

Source: Bowen et al. (2023)

Estimating Cost Shifting

[T]he bill alignment test (BAT) … compares the costs allocated to each customer with their electric bill, to help regulators consider how well a proposed rate design balances multiple regulatory criteria for designing retail tariffs.

-Simeone, et al. (2023)



Conclusion

- The power system is under multiple pressures that are challenging traditional approaches to rate design.
- Regulators may not be equipped with methods to evaluate innovative proposals, creating an obstacle to support.
- NREL has tools that can….
  - Ensure rates deliver revenue sufficiency
  - Forecast customer responses to rates
  - Evaluate rates across a variety of important regulatory considerations.

Thank You

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